APEC-ATCWG Workshop (2008)
Capacity Building for Risk Management Systems on Genetic Resources
205~232

The Status of Conservation, Utilization, and Risk Management of Genetic Resources in Taiwan

Sheng-Chung Huang[1], Ming-Che Wu[2], Fu-Guang Liu[3], Ching-Te Chien[4]

[1]National Plant Genetic Resources Center,
Taiwan Agriculture Research Institute, COA

[2]Division of Breeding and Genetics,
Taiwan Livestock Research Institute, COA

[3]Freshwater Aquaculture Research Center,
Taiwan Fisheries Research Institute, COA

[4]Division of Silviculture,
Taiwan Forestry Research Institute, COA

Abstract

Genetic resources may be used through complementary *ex situ* and *in situ* conservation approaches organized at the regional, national, and/or global levels. Genetic resources as defined in the *Convention on Biological Diversity* (CBD) refer to physical, tangible genetic materials as well as genetic information and knowledge. Five major germplasm conservation projects covering crops, forests, aquaculture, livestock, and microorganisms have been carried out at national institutes in Taiwan. The Plant Genetic Resources Center was established at the Taiwan Agricultural Research Institute in 1993. To September 2008, seed collections of 69,319 accessions are being conserved in long- and medium-term storage rooms. In field genebanks, collections and preservation of germplasm of fruit trees and medicinal plants include approximately 4968 accessions and are being maintained in several repositories. In total, 1745 accessions of clone germplasm collections are being cultured *in vitro* in tissue culture rooms. In addition, so far, more than 61,249

[1] Director, Division of Plant Germplasm, TARI. E-mail: schuang@wufeng.tari.gov.tw
[2] Director, Division of Breeding and Genetics, TLRI. E-mail: mcwu@mail.tlri.gov.tw
[3] Director, Freshwater Aquaculture Research Center, E-mail: fgliu@mail.fwlk.tfrin.gov.tw
[4] Research Fellow, Division of Silviculture, TFRI. E-mail: chien@tfri.gov.tw

accessions of genetically modified (GM) rice T_1 seeds and 32,799 accessions of T_2 seeds have been processed and conserved in a genebank. These seeds are available to distribute to scientists/ researchers for phenotypic screening or functional genomic research. The Tree Seed Bank was established by the Taiwan Forestry Research Institute in 1956. It conserves orthodox seeds of woody plants collected from natural forests for the perpetuation of seed stocks of 47 families, 151 species, and more than 700 seed lots. The conservation of farm animal genetic resources project was established by the Taiwan Livestock Research Institute in 1987 for further utilization of local breeds in the animal sector. New and emerging technologies, such as DNA library of local breeds, are being applied to reveal the genetic basis of disease resistance, adaptation to environmental stresses, and production efficiency. Capacity building for risk management of animal cells and/or tissues in cryopreservation banks with liquid nitrogen preservation has been in operation since 2005 to preserve valuable samples of fish and other aquaculture and fisheries species and wild relatives of livestock. Tilapia is one of the most important cultured freshwater fish species economically in Taiwan. In order to maintain its genetic variability and diversity, *in situ* bio-banks for stock breeds and conservation of tilapia and other aquacultured fish in culture systems were established by the Freshwater Aquaculture Research Center of the Taiwan Fisheries Research Institute in 2005.

Capacity building for management of germplasm described in this report is a key to stimulating sustainable utilization of genetic resources, especially local varieties/breeds. Action plans on risk management, safety conservation, species identification, hybridization, and commercial utilization of genetic resources for food and agriculture have been formulated to develop markets for biodiversity-based products. Efficient management of genetic resources is essential to ensure the present and future security of food and agriculture. As a participant in global efforts to conserve genetic resources, we expect greater benefits and responsibilities. Particularly, in term of global climate change and food crises, actions are needed to equip and manage genetic resource conservation systems as an effective component of national and international food and agriculture security.

Introduction

Taiwan is located along the boundary between the tropical and subtropical zones and is rich in biodiversity and ecological habitats. Although its areal extent is quite small, the biodiversity resources in Taiwan are extremely abundant, and there are diverse ecosystems due to the excellent geographical features and topographical environments. At present, there

are at least 6000 species of plants known in Taiwan, accounting for 2.1% of all plant species in the world, while at least 10,000 species of microorganisms have been recorded, accounting for 8.6% of the world's total, of which 2% are known to be endemic fungal species. Hence important questions concern how to more deeply understand characteristics of various ecosystems in Taiwan, how to better manage ecosystems, how to enhance the conservation of biodiversity, and how to sustainably utilize natural resources. These are the challenges currently facing the country and thus, are the main focus of technological development. Moreover, the rapid growth in agricultural production and economic development in recent years resulted in drastic reductions in the native flora of Taiwan. The genetic base of fundamental crops was narrowed by rapid progress in plant breeding and the large-scale adoption and frequent turnover of improved cultivars.

Genetic diversity refers to natural resources which are valuable and important global resources. Germplasm is indispensable material for the continued development of bioresources for food and agriculture in Taiwan. Agricultural scientists, including plant breeders are eager to use resources such as germplasm to improve crops. In view of the long-term needs of ecosystems, the sustainable conservation and utilization of genetic resources have drawn the attention of scientists and governments of all countries. To meet these increasing demands for genetic stocks and at the same time, to address concerns about the serious loss of biological resources, many nations have established genebanks to conserve and utilize plant genetic resources for food and agriculture.

Establishing national genebanks

At present, the focus of research and development on bioresources is on “the establishment of national germplasm banks” and “the effective management and utilization of bioresources”. To meet both national and global needs, the relevant institutes must recognize and act on the needs of the nation’s germplasm collections and conservation. Thus, five major germplasm conservation projects concerning crops, forests, aquaculture, livestock, and microbial genetic resources have been carried out at national institutes in Taiwan. These projects include a national system of collecting and conserving germplasm, evaluating native species, local species, and species related to folk use, as well as research on developing technologies for conservation, identification, and utilization. These are needed to establish an integrated national system of biological germplasm conservation and utilization, and ensure that bioresources can be sustainably managed and used.

Agricultural improvement depends on the utilization of abundant plant genetic resources and the carrying out of scientific research. Plant germplasm is indeed the basis of crop improvements and genetic variations, and biodiversity is the driving force for continued progress in plant breeding. The cultivation of hybrids and fixed commercial varieties has threatened the survival of indigenous varieties and wild plants. These primitive types may be genetically resistant to diseases or tolerant of environmental stresses and are considered to be precious sources of germplasm for utilization in the future.

Taiwan has realized the importance of sustainable conservation and utilization of plant genetic resources. The Plant Genetic Resources Center (PGRC) was established at the Taiwan Agricultural Research Institute (TARI) in 1993. The Center is administered by the TARI under supervision and funding by the government.

Collections and conservation of plant germplasm

Activities at the PGRC can be divided into four parts: collection, preservation, distribution, and research on the preservation and identification technologies of plant genetic resources. Germplasm collections include plants maintained in greenhouses and field plantings, dried seeds stored in sealed envelopes at low temperatures, and *in vitro* cultures of plant tissues and buds. The targets of collection include germplasm currently stored in seed units within the country, new varieties developed from breeding programs, genetic materials acquired from international exchange, and germplasm collected by exploration teams. Imported germplasm materials must be examined by the Bureau of Animal and Plant Health Inspection and Quarantine (BAPHIQ) for quarantine purposes to ensure importation of pest-free and viable materials for reproduction and distribution.

The methods for preservation of collected germplasm are based on the type of material: seed or non-seed (clonal materials). Seeds are the most commonly preserved form of germplasm. According to the level of seed tolerance to low temperatures and desiccation, seeds are further divided into storable and non-storable types. The majority of seeds of cereal grains, legumes, and vegetable crops can be stored for long periods of time under conditions of low humidity and low or subfreezing temperatures.

The conditions of storage rooms for long-, medium-, and short-term storage are –12±2 °C and 40%±3% relative humidity (RH), 1±2 °C and 40%±3% RH, and 10±2 °C and 40%±3% RH, respectively. Collections in long-term storage rooms are only preserved to regenerate fresh seeds and are periodically examined for seed viability. The main purpose of this storage

is for the perpetuation of seed stocks. The life expectancy of seeds preserved in long-term storage at this Center is between 30 and 50 years. The collections in medium-term preservation are for seeds that are actively used for distribution, exchange, multiplication, and evaluation. The seeds are also used to supply the base collection in long-term storage. Regular germination tests and seed regeneration are required for materials in storage in order to maintain seed viability and sufficient quantity. The short-term storage room is provided for storing breeder's working materials such as lines, parents, and progeny.

By September 2008, 76,032 accessions had been stored in long- and medium-term storage rooms, tissue culture rooms, or field repositories at the PGRC. These accessions represent 181 families, 703 genera, and 1071 species of plant germplasm. These seed collections include 31,832 accessions in the long-term storage room and 69,319 accessions in the medium-term storage room (Table 1). For the field genebank, collections of germplasm including fruit trees, medicinal plants etc., of approximately 4900 accessions are being grown and maintained in several repositories. In total, 1745 accessions of clonal germplasm are being preserved and cultured *in vitro* in tissue culture rooms at the TARI.

Table 1. Accessions of seed collections preserved in the PGRC in 2008

Crop	Scientific name	Passport data	Character data
Soybean	*Glycine max*	19,153	7438
Rice	*Oryza sativa*	7584	7760
Tomato	*Lycopersicon esculentum*	6860	124
Mungbean	*Vigna radiate*	6586	5000
Pepper	*Capsicum annuum*	3581	364
Eggplant	*Solanum melongena*	3120	470
Peanut	*Arachis hypogaea*	2124	1479
Common flax	*Linum usitatissimum*	1811	0
Sugarcane	*Saccharum officinarum*	1397	590
Asparagus bean	*Vigna unguiculata*	1338	258
Sweet potato	*Ipomoea batatas*	1321	596
Corn	*Zea mays*	1106	313
Lettuce	*Lactuca sativa*	706	0
Snap bean	*Phaseolus vulgaris*	617	147
Edible amaranth	*Amaranthus tricolor*	591	0
Sorghum	*Sorghum bicolor*	578	492

(Continued)

Black gram	*Vigna mungo*	538	0
Chinese cabbage	*Brassica campestris* Pekinensis group	536	0
Cucumber	*Cucumis sativus*	494	48
Spinach	*Spinacia oleracea*	417	0
Watermelon	*Citrullus lanatus*	403	67
Tobacco	*Nicotiana tabacum*	385	0
Muskmelon	*Cucumis melo*	343	177
Adzuki bean	*Phaseolus angularis*	286	245
Bitter melon	*Momordica charantia*	269	122
Cauliflower	*Brassica oleracea Botrytis group*	262	1
Peach	*Prunus persica*	260	183
Bottle gourd	*Lagenaria siceraria*	252	68
Jute	*Corchorus capsularis*	246	0
Luffa	*Luffa cylindrical*	242	225
Banana	*Musa* spp.	232	88
Snow pea	*Pisum sativum*	225	79
Chinese mustard	*Brassica campestris* Chinensis group	214	11
Chinese kale	*Brassica oleracea* Alboglabra group	206	109
Asparagus	*Asparagus officinalis*	205	100
Garlic	*Allium sativum*	204	214
Squash	*Cucurbita moschata*	203	49
Mango	*Mangifera indica*	183	22
Sunflower	*Helianthus annuus*	166	125
Mustard	*Brassica juncea*	166	20
Radish	*Raphanus sativus*	163	15
Taro	*Colocasia esculenta*	132	34
Buckwheat	*Fagopyrum esculentum*	128	0
Tea	*Camellia sinensis*	102	101
Wax gourd	*Benincasa hispida*	102	22
Others		7283	1455
Total		73,320	28,611

Genetically modified (GM) rice germplasm

Technologies of gene knockout and activation tagging have been developed, and they provide a direct route to determine the function of a gene. T-DNA insertion mutagenesis is one of the most popular methods for elucidating gene functions. Transgenic rice carrying T-DNA is being generated at Academia Sinica. Transgenic rice seeds carrying T-DNA are being produced at the TARI and preserved at the PGRC, TARI to ensure their quality and viability. At present, more than 61,249 accessions of rice T_1 seeds and 32,799 accessions of T_2 seeds have been processed and conserved in the genebank. These seeds are available to distribute to scientists for phenotypic screening or functional genomic research.

Clonal germplasm

For several reasons, germplasm of some crops cannot be stored as seeds. In such cases, germplasm must be maintained as live plants in the field or under cover (e.g., greenhouses or screenhouses), or as pollen, tissue cultures, or cuttings (e.g., scion wood of fruit and nut trees). Many clonal materials such as potatoes, sweet potatoes, yams, taro, strawberries, and some ornamental plants are cultured on artificial media in tissue culture (TC) room. TC allows rapid clonal propagation of a large number of plantlets over a short period, as well as maintenance of germplasm under controlled conditions in small spaces and with reduced labor requirements. TC techniques are space-saving and more intensively managed than techniques of field plantings. TC also ensures production of pathogen-free plants. Moreover, these materials are also desirable for international shipment and germplasm exchange.

At present, the TC room of the PGRC has preserved 810 strains of asexual reproductive germplasm, including 379 strains of sweet potatoes, 22 strains of potatoes, 17 strains of yams, 36 strains of taro, 16 strains of strawberries, 177 strains of lilies, 63 strains of chrysanthemum, seven strains of *Anthurium* of the Araceae, two strains of *Anoectochilus*, 74 strains of bananas, 15 strains of herbs, and one strain each of *Buplerum* and *Astragalus membranaceus*. They are all preserved in MS medium, at 20 °C, under 12 h of light and subcultured periodically depending on the species of plant.

Field genebanks

Germplasm materials such as fruit trees, potatoes, sweet potatoes, bananas, orchids, and medicinal plants are grown in seven repository gardens at different elevations and latitudes for conservation in various environments in Taiwan. The field genebank for preservation of vegetatively propagated crops is separately located in various agriculture institutes/organizations with major purposes of germplasm inspection, quarantine, nursery reproduction, and education about bioresource conservation. Total collections of the fruit tree repository include 45 families and 88 genera in about 800 accessions. In this repository system, tropical/subtropical fruits such as apple, plum, peach, pear, Chinese apricot, persimmon, grape, loquat, pineapple, longan, litchi, citrus, avocado, passion fruit, banana, papaya, mango, Indian jujube, star fruit, guava, wax apple, mulberry, and some exotic fruits are preserved in field genebanks (Table 2). The collections of medicinal plant germplasm preserved in field genebank include 23 species of ferns, one species of gymnosperm, 880 species of dicotyledons and 114 species of monocotyledons, among which 109 species are endemic to Taiwan.

Table 2. Germplasm materials of fruit trees grown in field nurseries for conservation

Repository garden	Preserved crops	No. of accessions
Wanshiang high-elevation field repository	apple, peach, pear	72
Loona middle-elevation field repository	peach, plum, Chinese apricot, persimmon	240
Wanfeng (TARI) low-elevation repository	grape, loquat, peach, plum, Chinese apricot, persimmon	178
Chiayi tropical and subtropical repository	pineapple, longan, litchi, citrus, avocado, passion fruit, banana, exotic fruits	596
Fengsan tropical repository	papaya, mango, Indian jujube, star fruit, guava, wax apple	311
Guansih citrus repository	citrus, pomelo	112
Kukeng field repository	tropical and subtropical fruit crops and woody flowering plants	13
Miaoli Agricultural Research and Extension Station	mulberry	138
Field nurseries at other places	fruit crops, medicinal crops, and others	3446
Total		4968

Seed regeneration

In order to maintain sufficient quantities and quality of seeds in genebanks, regeneration and characterization of the collected materials are carried out at TARI headquarters and by participating farmers and other collaborating institutes. Standardized procedures of seed regeneration are used. Regeneration procedures are based on standard protocols that take into consideration the breeding structure of each species in order to preserve the genetic integrity of the original population in the regenerated materials. In seed genebanks, the risk of introducing foreign genes or materials can occur anytime a seed sample is handled. Extensive care is taken during seed regeneration and processing with complete inspection and cleaning of all equipment used between accessions. These standard operating procedures continue throughout the storage and distribution processes to prevent admixing of seeds.

Cryopreservation

Plant germplasm stored in or suspended above liquid nitrogen at –150 to –196 °C may greatly extend storage periods. At the PGRC, embryos, shoots, and meristem tissues of crop germplasm such as grapes, bananas, papayas, strawberries, pineapples, sweet potatoes, mountain yams, cassavas, and orchids are preserved in liquid nitrogen at an extremely low temperature (–128 °C). However, its general application to germplasm management and utilization requires considerably greater knowledge and function than currently exists as well as a more-precise understanding of the protocols and control processes of cryopreservation.

DNA genebanks

DNA contains the molecular sequences that comprise genes. Thus, an organism's isolated DNA contains all of its genes. The potential to store isolated DNA underscores the central importance of germplasm as genetic information. This technology is already becoming available. At present, the NPGRC has established a crop genetic resource conservation system with the YAC genebank; in addition to saving storage space, the preserved DNA is suitable for biotechnological research and applications. Future objectives will focus on preserving important crop germplasm in Taiwan, including important released breeding varieties of crops and native plant species with potential for further development.

Germplasm distribution

Distribution of germplasm remains one of major functions of the PGRC. Germplasm materials stored at the PGRC are not only for conservation but also to support crop research and utilization programs in Taiwan. These genetic materials are available by request for academic purposes. The germplasm is distributed free of charge, and their related information is included as well for reference. The PGRC aims to serve as a storage site for all crops of Taiwan. Through international collaboration on collection and exchange of germplasm, we also aspire to become an international genebank for tropical and subtropical crops.

Germplasm information system

A computerized information system has been completed at the PGRC to strengthen collection, conservation, and utilization of crop germplasm, and modernize management and operation of plant genetic resources. This network system is linked to other germplasm information centers around the world. Researchers and breeders can use the linked net to obtain information and request plant genetic resources on the web site at: *http:/www.npgrc.tari.gov.tw*.

Conservation of forest genetic resources

Referring to the *Flora of Taiwan* published from 1993 through 2000, there are approximately 231 families and 1314 genera with a total of 3982 species of native vascular plants in Taiwan. Totally, there are 4216 species of vascular plants including 234 species which are invasive species which have been introduced and naturalized in Taiwan. A Tree Seed Bank was established at the Taiwan Forestry Research Institute (TFRI), Taipei, in 1956. The purpose of this genebank is to conserve orthodox seeds of woody plants collected from natural forests to perpetuate seed stocks. For seeds of orchards and plantation forests, these important recalcitrant seeds of woody plants are stored in moist sphagnum at 4 °C for short-term storage (1~3 years). The temperature of the storage rooms of the Tree Seed Bank is set to –20 °C for preserving orthodox seeds, and 4 °C for recalcitrant seeds.

Activities of the Tree Seed Bank include forest seed collection, preservation, research, and distribution. Research is necessary to understand the seed storage type for short- or long-term storage and dormancy-breaking methods for seed germination in nurseries. Seeds

stored at the Tree Seed Bank are not only for conservation but also for supporting plantation, afforestation, and international seed exchanges.

Species and classification of seed stocks at the Tree Seed Bank

The Tree Seed Bank is storing 47 families and 151 species of plants, comprising more than 700 seed lots. The genera, families, and species of tree seed collections are listed in Table 3.

Table 3. Woody species of plants conserved at the Tree Seed Bank, TFRI

GYMNOSPERMAE	
CUPRESSACEAE	
1. Calocedrus macrolepis var. *formosana*	*2. Chamaecyparis formosensis*
3. Chamaecyparis obtusa	
PINACEAE	
1. Abies kawakamii	*2. Picea morrisonicola*
3. Pinus armandii var. *masteriana*	*4. Pinus elliottii*
5. Picea morrisonicola	*6. Pinus massoniana*
7. Pinus taiwanensis	*8. Pseudotsuga wilsoniana*
9. Tsuga chinensis var. *formosana*	
PODOCARPACEAE	
1. Nageia nagi	
TAXODIACEAE	
1. Cunninghamia konishii	*2. Taiwania cryptomerioides*
ANGIOSPERMAE	
ACERACEAE	
1. Acer albopurpurascens	*2. Acer kawakamii*
3. Acer morrisonense	*4. Acer morrisonense*
5. Acer serrulatum	
ANACARDIACEAE	
1. Pistacia chinensis	*2. Rhus javanica* var. *roxburghiana*
3. Rhus succedanea	
AQUIFOLIACEAE	
1. Ilex asprella	*2. Ilex formosana*
3. Ilex lonicerifolia var. *matsudai*	*4. Ilex micrococca*
5. Ilex rotunda	
ARALIACEAE	
1. Dendropanax dentiger	*2. Schefflera octophylla*

(Continued)

BETULACEAE	
1. Alnus formosana	*2. Carpinus kawakamii*
BIGNONIACEAE	
1. Radermachia sinica	
BORAGINACEAE	
1. Ehretia longiflora	
CAPRIFOLIACEAE	
1. Sambucus chinensis	*2. Viburnum foetidem*
3. Viburnum odoratissimum	
CELASTRACEAE	
1. Celastrus kusanoi	
CORNACEAE	
1. Benthamidia japonica var. *chinensis*	
EBENACEAE	
1. Diospyros morrisiana	
ELAEOCARPACEAE	
1. Elaeocarpus japonicus	*2. Elaeocarpus sylvestris* var. *sylvestris*
3. Sloanea formosana	
EUPHORBIACEAE	
1. Bischofia javanica	*2. Sapium sebiferum*
FAGACEAE	
1. Castanopsis cuspidata var. *carlesii*	*2. Castanopsis fargesii*
3. Cyclobalanopsis gilva	*4. Cyclobalanopsis glauca* var. *glauca*
5. Cyclobalanopsis longinux var. *longinux*	*6. Cyclobalanopsis morii*
7. Cyclobalanopsis pachyloma	*8. Cyclobalanopsis stenophylloides*
9. Pasania glabra	*10. Pasania hancei* var. *ternaticupula*
11. Pasania harlandii	*12. Pasania konishii*
13. Quercus spinosa	*14. Quercus tatakaensis*
15. Quercus variabilis	
FLACOURTIACEAE	
1.Idesia polycarpa	
HAMAMELIDACEAE	
1. Liquidambar formosana	
JUGLANDACEAE	
1. Engelhardia roxburghiana	*2. Juglans cathayensis*
3. Platycarya strobilacea	

(Continued)

LAURACEAE	
1. Cinnamomum camphora	*2. Cinnamomum insulari-montanum*
3. Cinnamomum osmophloeum	*4. Lindera erythrocarpa*
5. Lindera megaphylla	*6. Litsea cubeba*
7. Litsea hypophaea	*8. Machilus japonica* var. *japonica*
9. Machilus japonica var. *kusanoi*	*10. Machilus philippinensis*
11. Machilus thunbergii	*12. Machilus zuihoensis* var. *mushaensis*
13. Machilus zuihoensis var. *zuihoensis*	*14. Neolitsea acuminatissima*
15. Neolitsea konishii	*16. Neolitsea sericea* var. *sericea*
17. Phoebe formosana	*18. Sassafras randaiense*
LEGUMINOSAE	
1. Acacia confusa	*2. Adenanthera microsperma*
3. Gleditsia rolfei	*4. Maackia taiwanensis*
5. Ormosia formosana	*6. Pongamia pinnata*
MAGNOLIACEAE	
1. Michelia compressa	
MELIACEAE	
1. Melia azedarach	
MORACEAE	
1. Broussonetia papyrifera	
MYRICACEAE	
1. Myrica rubra	
NYSSACEAE	
1. Camptotheca acuminata	
OLEACEAE	
1. Chionanthus retusus	*2. Fraxinus griffithii*
3. Fraxinus insularis	*4. Ligustrum sinense*
5. Osmanthus fragrans	
PALMAE(AREACACEAE)	
1. Phoenix hanceana	
PITTOSPORACEAE	
1. Pittosporum illicioides var. *illicioides*	
PROTEACEAE	
1. Helicia formosana	
RHAMNACEAE	
1. Rhamnus nakaharae	

(Continued)

ROSACEAE	
1. Eriobotrya deflexa	*2. Malus doumeri*
3. Photinia niitakayamensis	*4. Photinia serratifolia* var. *serratifolia*
5. Prunus buergeriana	*6. Prunus campanulata*
7. Prunus matuurai	*8. Prunus phaeosticta*
9. Prunus taiwaniana	*10. Prunus transarisanensis*
11. Pyracantha koidzumii	*12. Rhaphiolepis indica*
13. Sorbus randaiensis	
RUBIACEAE	
1. Tricalysia dubia	
RUTACEAE	
1. Phellodendron amurense var. *wilsonii*	*2. Tetradium glabrifolium*
3. Zanthoxylum ailanthoides	
SAPINDACEAE	
1. Dodonaea viscosa	*2. Koelreuteria henryi*
3. Sapindus mukorossi	
SCROPHULARIACEAE	
1. Paulownia kawakamii	*2. Paulownia ×taiwaniana*
SIMAROUBACEAE	
1.Ailanthus altissima var.*tanakai*	
STAPHYLEACEAE	
1. Euscaphis japonica	*2. Turpinia formosana*
STERCULIACEAE	
1.Reevesia formosana	
STYRACACEAE	
1. Alniphyllum pterospermum	*2. Styrax formosana* var. *formosana*
3. Styrax suberifolia	
SYMPLOCACEAE	
1. Symplocos stellaris	
THEACEAE	
1. Adinandra formosana var. *formosana*	*2. Cleyera japonica* var. *morii*
3. Eurya chinensis	*4. Eurya glaberrima*
5. Gordonia axillaris	*6. Schima superba* var. *kankaensis*
7. Schima superba var. *superba*	*8. Ternstroemia gymnanthera*
TROCHODENDRACEAE	
1. Trochodendron aralioides	

(Continued)

ULMACEAE	
1. Aphananthe aspera	*2. Celtis formosana*
3. Celtis sinensis	*4. Trema orientalis*
5. Ulmus parvifolia	*6. Zelkova serrata*
VERBENACEAE	
1. Clerodendrum trichotomum	*2. Premna microphylla*

The species of seed and clonal orchards are summarized as follows: *Calocedrus macrolepis* var. *formosana*, *Chamaecyparis formosensis*, *Cha. obtusa*, *Taiwania cryptomerioides*, *Cunninghamia konishii*, *Pinus taiwanensis*, *Michelia compressa*, *Cinnamomum osmophloeum*, and *Cinnamomum kanehirae*.

Tree seeds can be divided into three classes based on storage behavior: orthodox, recalcitrant, and intermediate types in Taiwan. Orthodox seeds are tolerant to desiccation, and they can be dried to moisture contents of 5%~6% and stored at –20 °C for more than 10 years. Examples of orthodox type of seeds are *Ca. macrolepis* var. *formosana*, *Cha. formosensis*, *Cha. obtusa*, *Taiwania cryptomerioides*, Leguminosae, Oleaceae, *Phellodendron amurense* var. *wilsonii*, *Schima superba*, *Koelreuteria henryi*, *Sapindus mukorossi*, *Liquidambar formosana*, etc. Recalcitrant seeds are sensitive to desiccation, and they cannot be dried and stored at any temperature, but can be stored with moist sphagnum at 4 °C for 1~3 years depending on the species. For example, seeds of most species in the Lauraceae, Fagaceae, and Podocarpaceae, including *Diospyros* spp., exhibit recalcitrant storage behavior. Intermediate seeds are between orthodox and recalcitrant types, and they can be safely dried to about 5%~12% moisture contents and stored at temperatures above zero (4°C) for a short period of 1~3 years. However, storage of intermediate type of seeds at subzero temperatures may reduce seed germinability and longevity. For example, seeds of *Cinnamomum camphora*, *Neolitsea aciculata* var. *variabillima, Schefflera octophylla*, *Trema cannabina*, and *Zelkova serrata* are categorized as having intermediate storage behavior.

Dormancy of tree seeds can be divided into four classes: physical dormancy, morphological dormancy, physiological dormancy, and morphophysiological dormancy. Tree seeds require scarification to break dormancy in species with physical dormancy such that *Acacia confusa* seeds require treatment at 100°C to break dormancy and increase germination rates. Other examples such that *Cinnamomum camphora* seeds need treatment with 15% H_2O_2 and *Sapindus mukorossi* seeds require treatment with concentrated H_2SO_4 to

facilitate germination rates. Most dormant tree seeds exhibit physiological dormancy and require cold stratification to break the dormancy. Some tree seeds exhibit morphophysiological dormancy and require warm and cold stratification to break seed dormancy.

Management, exchange, and conservation of animal genetic resources (AnGRs)

Conservation and utilization of AnGRs

Livestock and poultry in Taiwan include pigs, cattle, water buffalo, goats, horses, rabbits, chickens, ducks, geese, and turkeys (Figure 1). Other major poultry raised by local farmers include quails and ostriches. Due to high land prices and rising environmental awareness, most local farmers operate on a small scale in rural areas of central and southern Taiwan. Coupled with import-dependent feeds and expensive labor, the local livestock industry operates with rather high production costs. Fortunately, local livestock farmers are highly diligent, and have advanced feeding and breeding skills.

Figure 1. Farm animal genetic resources in Taiwan.

The existence of threats to AnGRs in developed countries due to globalization is generally accepted, and AnGR conservation is likely to be consistently undervalued. Native breeds generally maintain one or more adaptive characteristics to the living environment, which may provide useful or potentially useful genes or combinations of genes for future needs. Examples of useful genetic traits are prolificacy and early maturity of pigs, heat tolerance of Taiwan yellow cattle, disease-resistance of Formosan buffalo, roughage tolerance of native geese, and the meat flavor of native chickens. Furthermore, most native breeds of animals in Taiwan are still raised in grazing production systems. This was recognized at the 8th Board Meeting of the Advisors for Science and Technology – Agriculture Group in April 1986, which formally recommended that life resources be preserved so that their genes will not be forever lost due to concentration on limited and highly selected strains. Consequently a large-scale pilot national project, “Germplasm Preservation and Utilization in Domestic Animals”, was initiated in 1987. There are three methods for preserving livestock germplasm: maintaining live populations, cryopreserving germ cells, and establishing DNA stores. Animal resources are bounteous and are preserved for improving exotic breeds in terms of future production performance and efficiency. Conservation and integration of germplasm for new variants were attempts to adequately use the gene pool in Taiwan from 1987 to 1992. Protocols on conserving livestock germplasm are as follows:

1. Establishment of standards for visible characteristics of conserved breeds;
2. Collection of native animals from small farms;
3. Selection of places for conservation;
4. Propagation using a small population at random; if animals have economic traits for improving production performance of exotic breeds, then intercrossing programs are implemented;
5. Phenotypic measurements and data collection on animal growth, reproduction, living habits, and genetic polymorphism;
6. Preservation of germ cells with emphasis on semen and embryo cryopreservation;
7. Information exchange of utilization and provision for public needs;
8. Typical animals after propagation with benefits of cooperative germplasm research being released to the private sector;
9. Promotion of public extension and education with intellectual property rights for this germplasm relative to arts and culture; and
10. Sharing the world’s genetic diversity resources and turning potential into reality.

Capacity building in AnGR management

Understanding the diversity and status of AnGRs provides the basis for raising public awareness. However, raising awareness without ensuring capacities to realize actions will not produce the effective management and sustainable utilization of local breeds. Animal conservation activities were further posted on the web site of ANGRIN (*www.angrin.tlri.gov.tw*) for documentation of pictures and videos of conserved and selective breeding animals from 1993 to 1998 in the second phase of animal conservation project. The importance of the conservation and sustainable use of AnGRs was recognized by policy makers and major stakeholders in the livestock sector. Strengthening the breeding capacity and programs for local breeds were established and stimulated *in situ* conservation. On the other hand, *ex situ* conservation in cell/tissue banks requires appropriate infrastructure and organization, technical capacity, legal arrangements, and sustained funding. The Taiwan Animal Germplasm Center (TAGC) is a new capacity building for managing AnGRs via cell/tissue banks with liquid nitrogen, and it serves as a conservation center under the third phase (1999~2004) of the animal conservation project.

Research and utilization of molecular techniques to verify AnGRs are understood to encompass animal genetic resources that are or have been maintained to contribute to animal protein supplies and farmer livelihoods in the fourth phase (2005~2008) of the animal conservation project. Comprehensive assessments of genetic diversity of local breeds using molecular genetic markers are required. Genetic variations within livestock species are partly attributed to differences between breeds and partly to differences among individuals within breeds. A breed or population becoming extinct means the loss of its unique adaptive attributes. The potential of new and emerging technologies, such as DNA libraries of local breeds (Table 4), is being applied to reveal the genetic bases of disease resistance, adaptation to environmental stresses, and production efficiency. Molecular methods will provide new tools for conventional and trans-formative genetic improvements.

Domestic animals supply 30% of total human requirements for food and agriculture, and 70% of the world's rural poor depend on livestock as a component of their livelihoods. As an example, there have been tremendous movements of livestock germplasm from the northern hemisphere to Taiwan driven by global production systems as compared to that from the southern hemisphere to Taiwan. Exchanges of genetic materials among regions have been a very valuable mechanism for breeding and livestock development. Taiwan farm

animals such as dairy cattle, pigs, and layers, preserve a high percentage of exotic blood through long-term agriculture trade relationships.

Table 4. Establishment of DNA libraries for farm animals in Taiwan

Species	Breed/Line	Phage	Cosmid	Fosmid	BAC
Pigs	Taoyuan		1M1F		1M1F
	Lanyu		1M1F		
	Landrace		1M1F		
Cattle	Dairy Holstein			1F	
Goats	Formosan goat		1F		
Chickens	Native inbred line 9		1M1F		1M1F
	Native inbred line 11		1M1F		
Ducks	Brown Tsaiya	1F			
Geese	Brown native			1F	
	Total	1	11	2	4

Backup system for global management

Further losses of local breeds are probably inevitable, even though local breeds are important components of our future food security and cultural heritage. Conservation of local breeds should certainly be a public concern. In the fifth phase (2009~2012) of the Taiwan animal conservation project, a global bio-identification system and exchanges of genetic resources will be carried out to develop a backup system of genetic materials and samples at the regional and global levels. Therefore, TAGC's mission consists of effective and efficient handling and documentation of AnGRs such as DNA samples, cells, and tissues generated from various germplasms in AnGR conservation, cryobanking, bioutilization, and management as follows:

1. To provide a venue to discuss the status of documentation activities of the various cryobanks of animal and forage plant genetic resources in the Asian and Pacific region;
2. To familiarize participants with various documentation systems available, germplasm documentation, data analysis, and information management for AnGRs;
3. To reinforce the capabilities of participants for conservation banking techniques, cell freezing methods, data processing, genetic analysis, and interpretation of results;

4. To provide a venue to discuss and clarify issues concerning international, regional, and national laws and policies of relevance to the conservation and management of AnGRs;
5. To increase the knowledge and understanding of participants on intellectual property rights (IPR) issues, mechanisms of access, and benefits of sharing genetic resources; and
6. To reinforce the capability of participants in dealing with said issues in relation to research and development of AnGR conservation and management.

High-output breeds or so-called international trans-boundary breeds have resulted in impressive production increases, and many countries regard them as a means of enhancing their livestock production to replace local breeds (FAO, 2007). The capacity to characterize, sustainably use, and conserve AnGRs in many countries varies due to a lack of inventory and monitoring. Moreover, inventories of AnGRs are the basis for planning development programs of local breeds. Collaboration in breeding activities between countries with similar production conditions is an opportunity to share costs and make breeding programs more sustainable. Animal health is the most regulated aspect of livestock management on a global scale. Hence, effective disease control is essential, and trade potentially presents challenges for AnGR risk management and backup systems.

In order to facilitate the collection, conservation, utilization, exchange, rehabilitation, and research of farm animal and forage genetic resources, as well as to solidify the operations and management of farm animal and forage genetic resources, the *Operation Guidelines* (document no. 0962300511 of the Council of Agriculture (COA) on January 19, 2007) were set up by the Taiwan Livestock Research Institute (TLRI). Genetic materials collected and conserved by the TLRI belong to the government, while the original provider retains the preferential right to take back part of the conserved genetic material. Under this condition, the original provider retains the preferential right to take back all of the conserved genetic materials stored at national backup inventories for risk management. When the utilization of biological materials involves IPR, the operation shall proceed in accordance with ‘’the regulation for the belongings and utilization method of scientific research and development achievements,’’ promulgated by the COA. Therefore, genetic materials of fish and other aquaculture and fisheries species, and wild relatives of livestock are kept in the cryobanking capacity of the TAGC for risk management of valuable samples. This backup concept for global genetic resource management should take the same approach among

countries and regions. A global program should be formulated to provide the institutional capacities and resources needed for its implementation at the regional level and to accept the global responsibility.

Aquatic genetic resourcebank (AGRB) at the freshwater aquaculture research center (FARC)

Tilapia fish have been cultured for nearly 60 years in Taiwan since the introduction of Mozambique tilapia (*Oreochromis mossambicus*) in 1946. At present, seven species of tilapia have been introduced and are being conserved in Taiwan. Successful hybridization and efficient selective breeding have resulted in significant development of fast-growing strains and all-male fry. These achievements have promoted the rapid development of the tilapia industry in Taiwan. In 2007, the annual production of tilapia reached 76,000 metric tons (mt), which ranked first among the top ten aquaculture species in Taiwan (Table 5). Tilapia has become the most important exotic fish species cultured in Taiwan.

Due to environment pollution, degradation of natural habitats, invasion of exotic species, and inbreeding depression of aquaculture species, the establishment of aquatic genetic resources bank is urgently needed. The objective of this genetic bank would be to facilitate the implementation of selective breeding and broodstock conservation for both economically cultured species and native fish species in rivers. Broodstock management and species identification, hybridization and its commercial application, and breeding achievements in recent years are summarized.

Table 5. Production, value, and acreage of main aquaculture species in Taiwan (2007)

Species	Metric tons ($\times 10^2$)	Value (10^6 TWD)	Area (ha)
Tilapia	761	2656	6964
Milkfish	532	2462	8865
Eel	248	7613	2006
Hard clams	357	1597	6892
Oysters	282	3215	11798
Groupers	172	3884	1554
Freshwater clams	145	592	1015
White shrimp	101	1814	2289
Giant freshwater prawn	83	3129	1948
Carp	73	357	2072

Establishment of an aquatic genebank

In order to preserve genetic diversity, secure natural resources, and improve genetic breeding of aquatic fish, the FARC was designated as the base for an aquatic genetic resource bank in 1998. After national considerations on the details of the proposal, the design of this institute was completed in 2003; construction began in 2004 and was completed in November 2005. The main facilities include a genetic conservation building, breeding and genetic building, and conservation greenhouses. The breeding and genetic building is utilized as a site for breeding and genetic conservation of tilapia. The facilities of the genebank include different-sized broodstock ponds and water recirculation systems. In addition, the conservation greenhouse is the site for preserving tilapia seedlings. The building is equipped with electric windows and fans to adjust the room temperature.

Tilapia stocks at the FARC

Oreochromis mossambicus was first introduced to Taiwan from Singapore in 1946. A low tolerance to cold temperatures and small size are two major disadvantages in fish farming. *Tilapia zillii* was later introduced from South Africa in 1963. This species did not receive much acceptance due to poor taste and slow growth. *Oreochromis niloticus* was introduced from Japan in 1966 for the purpose of genetic enhancement. In addition, for the sake of obtaining monosex progeny, *O. aureus* was introduced from Israel in 1974. Since then, two species have been added to the list of tilapia in Taiwan, *Tilapia rendalli* from Costa Rica and *O. hornorum* from South Africa, again for the purpose of genetic improvement. Additionally, the introduction of *O. spirulus* in 1991 from Saudi Arabia was due to its eurythaline features. Tilapia species stocked at the FARC are shown in Table 6.

Management of fish stocks and species identification

Because the retarded growth of cultured tilapia was largely due to poor broodstock management, resulting in inbreeding depression, much attention had to be paid to broodstock management.

Table 6. Tilapia species stocked at the FARC

Species	Year introduced	Source
Oreochromis mossambicus	1946	Singapore
O. mossambicus	1981	South Africa
Tilapia zillii	1963	South Africa
O. niloticus	1966	Japan
O. aureus	1974	Israel
O. hornorum	1981	Costa Rica
T. rendalli	1981	South Africa
O. spilurus	1981	Saudi Arabia

Generally, both broodstock and offspring are kept in ponds for two to three generations. Mass selection was adopted to carry out selective breeding. During the spawning season (from April to May), fish with superior qualities are selected to serve as spawners and are stocked in a pond for natural reproduction. Before overwintering, larvae with a large size, fast growth rate, and high conditioning factor are captured and serve as genetically superior seedlings. These fish are conserved for future use.

As for the genetically effective population (Ne), the following formula is used:

$$Ne = (4 \times N♂ \times N♀) / (N♂ + N♀).$$

If, ♂ : ♀=1 : 1,

then, Ne = 2Np.

Usually, the inbreeding rate (IR) = 1／(2Ne).

If the IR maintains below 0.25%, Ne should not be < 100 pairs for each conserved species, which is required to maintain healthy genetic variability.

Methods developed to use for species (strain) identification are listed as follows:

a. Data collection and assessment of digital pictures;
b. Data establishment of morphometric and meristic characters;
c. Analysis of chromosome – set distribution (or karyological analysis);
d. Allozyme electrophoresis – using serum esterase, hemoglobin, transferrins, and serum protein;
e. Mitochondrial DNA (mt-DNA) – polymerase chain reaction (PCR) and restriction fragment length polymorphism (RFLP) analysis; and
f. Genomic DNA – random amplified polymorphic DNA (RAPD) techniques.

Hybridization and utilization of fish stocks

Increases in production will have to come from the use of genetically improved strains. Consequently, applications of selective breeding and hybridization have been responsible for increased production efficiencies and improved productivity.

Tilapia mature at as early as 4 months old and spawn multiple times. In addition, male tilapia grows about 1.5~2-fold faster than females. Therefore, it is a common practice to culture all-male tilapia. There are two important factors which contributed to the success of commercial tilapia culture: strains with faster growth rates and larger size and production of all-male fry.

Hybridization between female *O*. *mossambica* and male *O*. *niloticus* was achieved in 1969. The hybrids have the genetic merits of a faster growth rate and larger size. This hybrid strain resulted in the rapid development of tilapia culture in Taiwan. Hybrids between female *O. niloticus* and male *O. aureus* were obtained which produced a high percent of male progeny in 1975. The culture of all-male fry successfully brought the tilapia industry into commercial-scale production in Taiwan.

Hybrids derived from *O. niloticus* and a mutant of *O. mossambicus* by interbreeding were obtained and have been maintained since 1968. After successive selective breeding, a pure-red color strain was recently produced with only a few spots, and in some cases, not even a single spot (Figure 2).

Currently, *O. niloticus* is the target species for experiments of selective breeding. To the present, four conserved strains have been selected and exhibit good growth performance. In view of the fact that some of the strains hybridized with *O. aureus* could produce 100% all-male progeny, tilapia species are being conserved in the genetic resource bank of the Center.

A faster-growing strain of tilapia was developed in 2006 through hybridization of *O. niloticus* and *O. aureus.* This strain showed a 30% higher body weight on average compared to locally farmed strains.

Digestion of the D-loop region, using *Acu*I, *Bbs*I, and *Msp*I restriction enzymes, resulted in several different restriction patterns. This PCR-RFLP technique was developed in 2007 to discriminate five tilapia species conserved at the FARC.

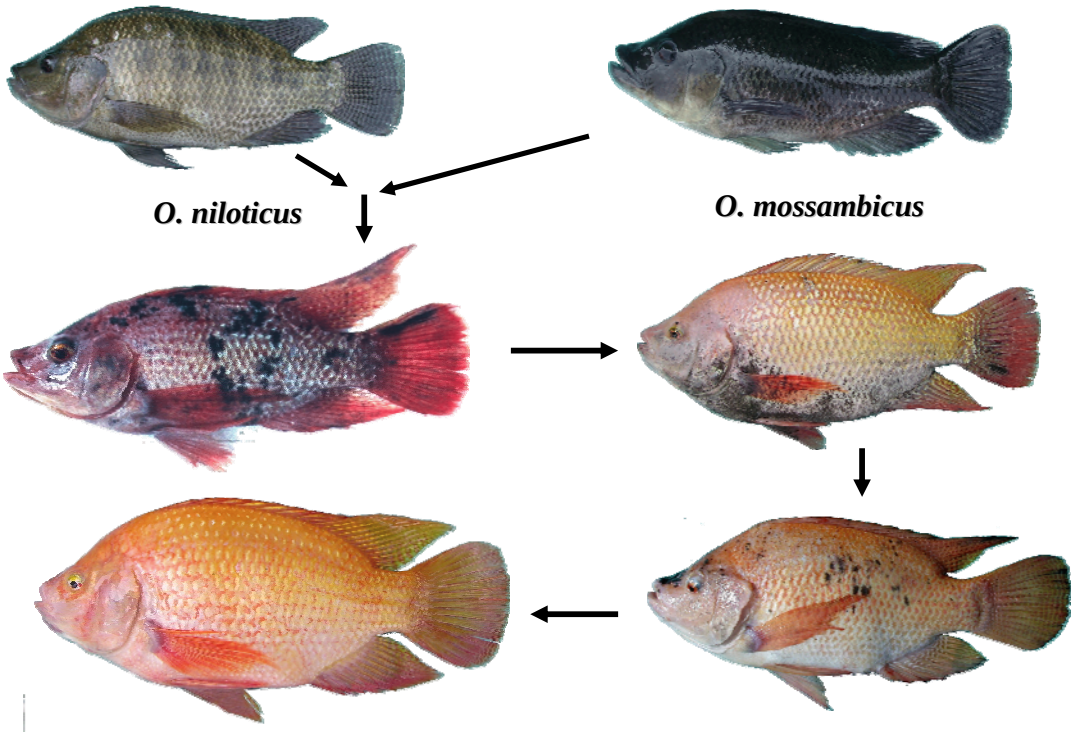

Figure 2. The pure-red strain of tilapia derived from interbreeding of *Oreochromis niloticus* and a mutant of *O. mossambicus*.

The coloration of red tilapia varies with size and environmental conditions. In addition, black spots also appear in the late period of culturing. There seems to be a tendency for its genetic expression mainly from a recessive gene. The experiment of selective breeding accordingly focused on increasing homozygous mating.

After long-term crossbreeding, the effects of inbreeding depression are likely to occur due to genetic bottlenecks resulting from very few fish having been imported originally. Since importation is very difficult to achieve, devising a good approach to prevent this negative effect is, therefore, the first priority. From the viewpoint of genetic variance, wild stocks are more important than cultivated ones. In this aspect, there is an eager requirement to introduce wild stocks from foreign countries.

Risk management of agricultural genetic resources

Risk management

The objectives of risk management are first to recognize the duty, mission, and policy implementation of the institute, determine the risks that can effect the objectives of policy implementation of the institute, and appreciate the internal and external environments for policy implementation when it is to make decisions. Then, these events will be researched and analyzed, and the extent of the impacts of actions can effectively be managed to lower risks, and the probability can be minimized even in a crisis. Therefore, when events occur, theirs impacts can still be minimized.

The government began to facilitate implementation of risk management for institutes and organizations in 2005, and it has sponsored risk management for executive and professional study classes, compiling operation manuals of risk management, and establishment of a risk management knowledge network and an expert counseling hotline to promote the beliefs in risk management as well as to advocate the fundamental concepts of risk management for integration with domestic and overseas knowledge and experiences. Furthermore, it has also introduced measures of implementation in the public sector to conduct an integrated cooperative framework and practical operations of risk management. In addition, the government has included “risk management” in the program content of management study camps of public servants to enhance their capability building.

Risk mitigation

Natural risk mitigation strategies can reduce the impacts concentrated on our nation’s genetic resources, large employment, public infrastructure, and critical facilities. Natural risk mitigation for genebanks may include developing emergency management services and training employees’ capability to deal with a contingency before an event occurs, and establish mitigation strategies. Collaboration among the public and private sectors to create mitigation plans and actions can reduce impacts of natural hazards. In developed countries such as Canada, the UK, and Australia, their government departments have, for years, introduced risk management, while we have merely just begun to consider risk management. Therefore, the concepts of integrated risk management of every institute remain at the initial stage. Capacity building of risk management for institutes desperately needs greater inputs and efforts. We believe that losses resulting from risks can be reduced, and more success can be achieved through effective implementation of risk management.

Capacity building

Seed genebanks are established to maintain the viability and life-span of plant seeds in the long term. As a result, banks should be equipped with facilities to maintain low temperatures and low humidities as well as to endure natural environmental changes and man-made disasters. Furthermore, they should also be staffed with professional personnel and have the financial resources to maintain regular operation of relevant management systems.

In the world of nature, there may be disasters that can generate relatively large-scale risks to seed banks; 1. abiotic disasters such as earthquakes, flooding, fires, landsides, lightning strikes, and flying objects, which may result in the collapse and destruction of seed banks; and 2. biological disasters including the destruction and poaching by microorganisms, insects, birds, mice, animals, and human beings.

To strengthen the buildings and facilities, seed genebanks are constructed to withstand earthquakes, floods, typhoons, and other natural disasters. In addition, the structure of the building can withstand an earthquake of up to magnitude 7 on the Richter scale (while regular buildings can withstand a magnitude 5 quake), and the building is of a stabilized square-structure with a raft foundation so that the entire building vibrates with the quake to reduce damage. As for fire-fighting equipment, most office buildings make use of fume-detection sprinkler systems, while mechanical warehouses with lubricant oil heat-detection and self-solid systems of fire fighting equipment will be installed. In the seed bank, the computer room and seed bank have fume-detection and heat-detection inertial gas fire-prevention systems to prevent equipment and plant species from being destroyed by fire-detection sprinklers in the seed bank. In front of the building, there is a pool for fire-fighting vehicles during a fire. Furthermore, the seed bank building is designed so that the core of the building can withstand a collision with a flying object, and it is then surrounded by various other buildings.

In most developing countries, capacity building for managing seed genebanks and field genebanks lacks long-term support for national management systems of genetic resources, which results in a lack of effective access to germplasm and relevant technologies. Other limitations have to do with insufficient trained personnel, shortcoming of facilities, and inefficiencies in administration. Raising the capacity to manage genetic resources at the international, national, and regional levels requires the training of more experts and curators/stakeholders and the development of an integrated risk management system. The

TARI has drawn mid-term specific objectives for capacity building strategies aimed at enhancing integrated management systems of national genebanks. These strategies support policy development, provide education and training, facilitate access to relevant technologies, construct back-up systems for global management, and facilitate exchange of genetic resources and sharing of information to effectively utilize genetic resources to meet producer and consumer needs and address food security and livelihood concerns.

Conclusions

The nursery industry and utilization of bioresources including plants, aquaculture, livestock, and microorganisms, are considered the most potentially competitive agriculture industries in Taiwan. In recent years, because species improvement has targeted high yields and uniformity so that the materials used tend to certain genotypes, broadening the genetic diversity to enhance the adaptability of new species is a necessary measure for resource conservation and future nurseries. These measures involve collecting native and exotic species for trait investigation and conservation, updating germplasm year by year to ensure the genetic security of strains/stocks/varieties so as to maintain and utilize the genetic resources for food and agriculture.

Biodiversity is the key research topic of global interests. Other than research on diversity of ecosystems, species, and genetics, using molecule technologies makes research on genetics and gene diversity more convenient and rapid. Planning measures and policy decisions of bioresource conservation must refer to more bioinformatic information on the genetics, species, and ecological diversity involved. The establishment of DNA bar codes of species and gene databases will help researchers share bioinformatics of genetic resources. To access germplasm materials for global ecological conservation and sustainable use, establishing a nation’s genebanks and preservation of germplasm are effective ways to efficiently utilize natural resources, and overcome global climate changes while simultaneously improving food and agricultural production.

Biological diversity is a natural resource. All nations share the responsibility for its management and the privilege of using it. Individuals, the private sector, and other groups can contribute to the maintenance of germplasm, but the tasks of overseeing and managing genetic resources are clearly beyond the capacity of any individual or group. Coordination of the many varied efforts including international collaboration must occur through fully supported and funded national programs.